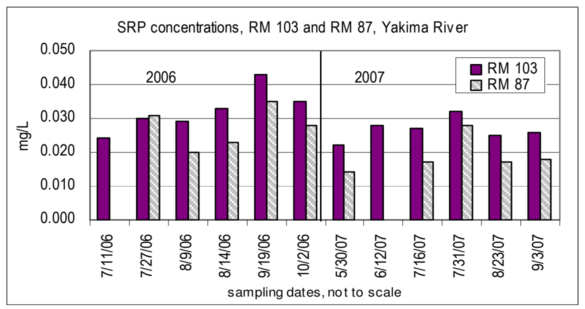
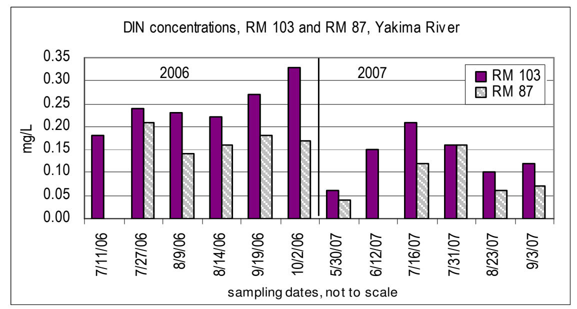
Evidence for Plant Uptake: Concentrations Decrease Through 16 Miles of the Zillah Reach

Dissolved inorganic nitrogen (DIN) and soluble reactive phosphorus (SRP) concentrations were higher just below the Sunnyside Diversion Dam at river mile 103 than near Zillah at river mile 87 in all but two samples collected during 2006 and 2007. Further, in five out of ten sets of samples, the declines in DIN and SRP concentrations between the upstream and downstream sites followed a 7.2 N to 1 P ratio — the same proportion required by most algae. These two observations, combined with nuisance-level periphyton growth in the reach, were strongly suggestive of algal uptake as the cause of the decreased nutrients. Algae were able to take up more nutrients than were added by the nutrient sources (treatment plant, irrigation wasteways, etc.) coming into this portion of the Zillah reach.





Future Management Considerations

In future years, the Department of Ecology will use a mathematical model to determine how low nutrient concentrations need to be in the Yakima River to 'starve' the algae and meet state dissolved oxygen and pH standards. Based just on the types of nutrient sources in each reach, management considerations include the following:

Because such a high proportion of the nutrient load in the Kiona reach comes from upriver, in order to lower nutrient concentrations in the Kiona reach, it will be necessary to decrease nutrients in the Mabton and Zillah reaches.

In the Mabton reach, irrigation return drains were the largest source of nitrogen; upstream sources contributed the largest loads of phosphorus. The largest return flow in this reach, Sulphur Creek Wasteway, has a wealth of data from the Roza-Sunnyside Board of Joint Control. Based on their data, from 1997 to 2002, the median (typical) total phosphorus load from Sulphur Creek Wasteway decreased by 71% — a significant improvement. But since 2002, median loads have been variable, neither consistently decreasing or increasing. Phosphorus concentrations have been unexpectedly higher during the non-irrigation season than the irrigation season since 1999, suggesting that our current understanding of how phosphorus moves into and through irrigation return drains is incomplete. Median nitrate concentrations have varied between 1.5 and 3 mg/L during the irrigation season since 1997 — very high concentrations in terms of promoting algal growth. Most of the nitrate comes from groundwater. From a clean-up perspective, it can take decades to decrease nitrate concentrations in groundwater, depending on local conditions.

In the Zillah reach, the largest sources of DIN came from irrigation return drains/tributaries and the upper Yakima River. The largest source of SRP was wastewater treatment plants. Upgrading wastewater treatment plants to decrease nutrient concentrations can be very expensive, depending on the target effluent concentrations, which will be determined by the future modeling work.

Conclusions

Nutrient concentrations in the lower Yakima River increased from Selah Gap to downstream of the City of Yakima, decreased until below Zillah, increased until Prosser Dam, then declined. The declines were likely due to algae taking up more nutrients than the relatively small sources contributed in the Kiona reach and part of the Zillah reach. In contrast, large inputs of nutrients to the lower Zillah and Mabton reaches exceeded the uptake rate by algae, resulting in a rapid increase in nutrients in the river. In the Zillah reach, upwelling of nutrient-rich hyporheic water occurred in some places but not in others; the relative importance of this process on a reach-scale was not assessed. The largest sources of nutrients differed between reaches, suggesting future management strategies need to be reach-specific. Nutrient concentrations in all reaches of the lower river were high enough to support nuisance levels of algal growth.

This handout is one of a series of five handouts on different topics relating to nutrient-enrichment processes in the lower Yakima River. For more information, contact the South Yakima Conservation District at (509) 837-7911.

Nutrients in the Lower Yakima River

South Yakima Conservation District

April 2008

Benton Conservation District

The U.S. Geological Survey, South Yakima Conservation District, and Benton Conservation District worked together to study the lower 116 miles of the Yakima River from 2004 through 2007 to learn more about nutrients, algae, rooted aquatic plants, and dissolved oxygen and pH conditions in the river. Why the concern? Nutrients encourage excessive plants and algae, which in turn can cause poor dissolved oxygen and pH levels from photosynthesis. Two goals of the study were to identify nutrient sources and how nutrient concentrations varied in the lower river and over time.

The opinions and conclusions expressed in this flyer are those of the conservation districts, not the U.S. Geological Survey. The final project report from the USGS is scheduled to be completed this fall. This and other handouts are being provided before the final report because of timing constraints from grant funding.

Introduction

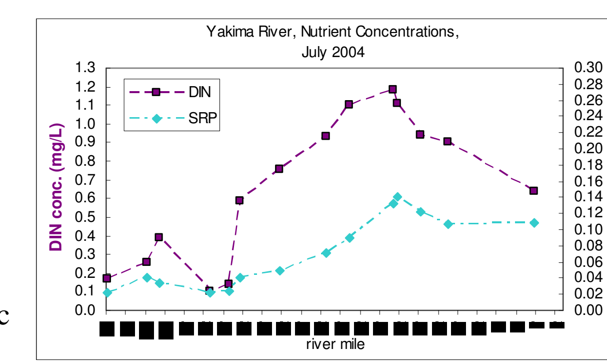
Aquatic plants and algae require three major nutrients to grow: carbon, nitrogen, and phosphorus. The main sources of carbon for aquatic plants and algae are carbon dioxide from the air that has been introduced into the water and respiration by organisms living in the river. In free-flowing waters, the supply of carbon required by plants and algae usually far exceeds the demand for it. In contrast, the supply of phosphorus or nitrogen in some rivers is less than the demand, which limits the amount of aquatic growth (e.g., the algae is 'starved' for an essential nutrient). Thus, in rivers with nuisance levels of algae, one strategy to reduce the amount of algae is to reduce the amount of nutrients added to a river. This is not generally considered an option for managing rooted aquatic plants because they are able to obtain nutrients from either the river bed through their roots or the water column through their leaves. Where do nutrients in rivers come from? Major sources include fertilizers and sewage treatment plants. In some rivers, native rocks and soils naturally high in phosphorus can also be an important source. The biologically-available forms of nutrients include dissolved orthophosphorus (sometimes called soluble reactive phosphorus or SRP) and dissolved inorganic nitrogen (DIN), which includes nitrate-plus-nitrite and ammonia.

To identify nutrient sources and changes in nutrient concentrations over the entire 116 miles of the lower Yakima River, nutrients were sampled once in June 2004 using a synoptic or 'snapshot' sampling approach from 16 river sites, 8 irrigation return drains, 7 creeks, 6 sewage treatment plants, 4 return flows, and 5 diversions. In 2005 through 2007, individual reaches were sampled more often, providing a better understanding of changes in nutrients within a given reach.

2004 Synoptic

Patterns in Nutrient Concentrations

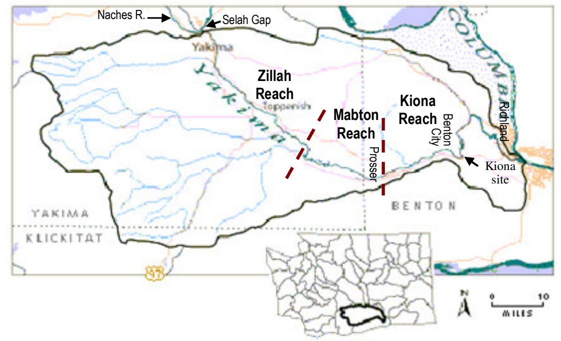
Nutrient concentrations in the lower Yakima River in July 2004 increased from Selah Gap to downstream of Yakima, decreased until below Zillah, rapidly increased until Prosser Dam, then declined (see chart to the right). The declines were likely due to uptake of nutrients by algae and possibly some species of aquatic plants. The increases were due to irrigation returns and wastewater (sewage) treatment plants, in varying degrees of importance, as discussed on the next page.



The high DIN concentration at RM 103.8 was due to an unusually high ammonia concentration of 0.17 mg/L. It was considered unusual because none of 12 samples from a nearby site in 2006-2007 had an ammonia concentration above 0.04 mg/L.

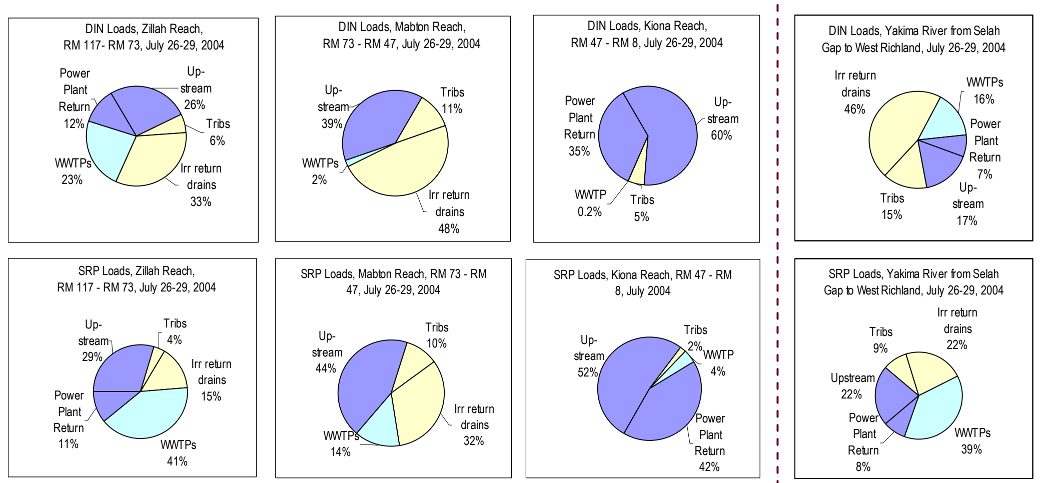
Loads

What are the major sources of nutrients in the Yakima River? Based on the nutrient concentrations and flows measured during the 2004 synoptic, loads (the pounds per day of each nutrient) were calculated for each source. Over the entire 116 miles, the largest source of DIN was irrigation return drains. The largest source of SRP was wastewater treatment plants (WWTPs). These overall numbers, however, mask significant differences between the three reaches.



In the Zillah reach, the largest sources of DIN were irrigation return drains/tributaries and from upstream; the largest source of SRP was wastewater treatment plants. In the Mabton reach, irrigation return drains were the largest source of nitrogen while the largest source of phosphorus was from upstream. In the Kiona reach, of the identified sources, nearly all of the nutrients in the river were from upstream sources, either passing over Prosser Dam or through the Chandler Power Plant return.

Nutrient Sources, by Reach | **Nutrient Sources, Overall**



Zillah reach sources: Naches R, Roza Power Plant Return, Yakima WWTP, Wide Hollow Ck, Moxee Drain, Ahtanum Ck, Zillah WWTP, East Toppenish Drain, Sub-drain 35, Granger Drain, Granger WWTP, Marion Drain, Toppenish Ck, Coulee Drain.
Mabton reach sources: Satus Ck, South Drain, Sulphur Ck Wasteway, Satus Drain, Mabton WWTP, Grandview WWTP.
Kiona reach sources: Prosser WWTP, Spring Ck, Snipes Ck, Chandler Power Return, Corral Canyon Ck.

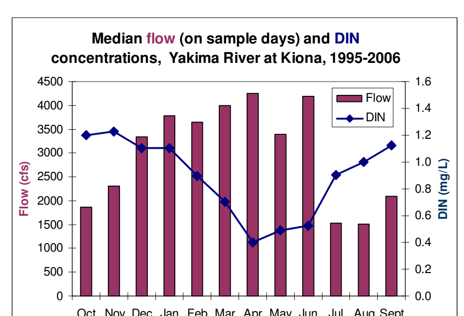
How High is High?

There is no state standard against which to compare nutrient concentrations in the Yakima River. Biologically, there are high enough nutrient concentrations in the river to support luxuriant algal growth even in the reach with the lowest nutrient concentrations. In comparison to other rivers, a 1999 U.S. Geological Survey (USGS) report found that the median (typical) concentration of nutrients at Kiona during 1987-1991 was similar to the median value of 354 U.S. rivers sampled near their mouths. Numerous researchers and agencies have struggled for years to identify concentrations which prevent nuisance algal growth. A few examples are shown in the table to right, illustrating the wide range in their recommendations. In Washington State, the Department of Ecology has chosen to identify nutrient goals on a river-by-river basis, for those rivers with dissolved oxygen or pH violations.

Agency/researcher	N (mg/L)	P (mg/L)
Dodds, 2004 (Xeric west)	0.92 Total N	0.15 Total P
EPA, 2000 (Ecoregion 3)	0.38 Total N	0.03 Total P
New Zealand, 2000	0.10 DIN	0.01 SRP
Lower Yakima River, 2004 synoptic conc.	0.10 to 1.20 DIN 0.29 to 1.52 Total N	0.02 to 0.16 SRP 0.05 to 0.20 Total P

How Well Did the Synoptic Represent Typical Conditions?

Nutrient concentrations in the lower Yakima River are strongly influenced by the volume of water in the river — as volume increases, nutrient concentrations tend to decrease. Why? Flow increases in the Yakima River mostly from melting snow, return flows, or reservoir releases, all of which typically have lower nutrient concentrations than groundwater and so dilute nutrients present in groundwater. Nutrient concentrations are generally highest during winter months when flows are low and consist mostly of groundwater. The 2004 synoptic represents only a small moment in time under one set of flow conditions. It is powerful data because it compares so many sites in a



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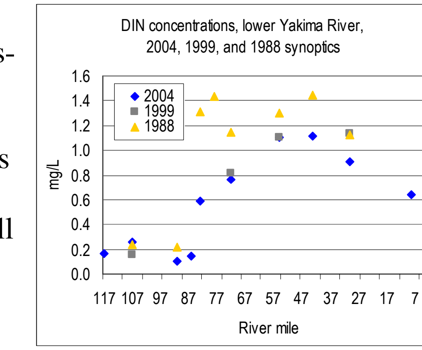
The Department of Ecology has sampled the river at the Kiona site on a monthly basis for many years. The DIN concentration at Kiona during the July 2004 synoptic was 0.9 mg/L, the same as the July median concentration of 0.9 mg/L from the Department of Ecology's data for 1995-2006. The SRP concentration in 2004 was 0.11 mg/L, as high as the highest 10% of the Department of Ecology's data for the same time period.

The USGS also conducted synoptics in July 1988 and August 1999. How did the July 2004 results compare? SRP concentrations in 2004 were neither consistently higher or lower than the other years. DIN concentrations in 2004 tended to be lower than the other years, although flows in 2004 were not highest of the three synoptics. Flows passing over Sunnyside Dam were 160, 680, and 380 cfs in the 1988, 1999, and 2004 synoptics, respectively and at Kiona were 1000, 1800, and 980 cfs, respectively. The general pattern, however, was similar in all three years — relatively low concentrations from river mile 117 to 83 and increasing concentrations thereafter.



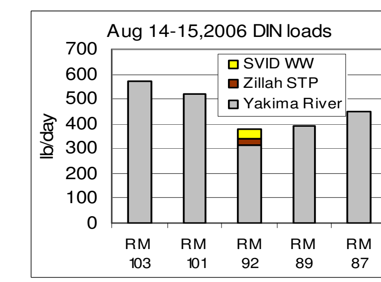
Zillah Reach Nutrients

In 2006 and 2007, nutrients were sampled frequently in a 16-mile section of the Zillah reach, from the Sunnyside Diversion Dam to near Zillah. This section of the river was selected for more intensive study due to its high abundance of algae and greatest potential for improving conditions through nutrient reduction efforts, since this reach had the lowest concentrations in the lower 116 miles.

Sources

Surface water inputs

In the Zillah reach from the Sunnyside Diversion Dam to just downstream of Zillah, surface water inputs include Roza Wasteway #3, Joint Drain 14.6, Sunnyside Division Wasteway, and the Town of Zillah's wastewater treatment plant (WWTP). In 2006, five sites in the reach and the WWTP were sampled on one day each in March, August, and October. Joint Drain 14.6 was not sampled because of its small flow and negligible loads (prior sampling had determined it contributed less than two pounds per day). On the sampling days, the wasteways often had little or no discharge — Sunnyside's discharged only in August and Roza's discharged only in October. While the relative proportions of sources varied on different days, the overwhelmingly largest source of nutrients remained the same — water coming from upstream of Sunnyside Diversion Dam.



Because flows at RM 103 and 87 were comparable in the 2004 synoptic, flow was not measured in 2006 at each sampling site to calculate loads, instead relying on the Paker gaging station for all flow values.

Groundwater inputs

Water from the hyporheic zone — where surface water and groundwater intermingle below the river bed — can have higher nutrient concentrations than surface water. All 14 sites where the hyporheic zone was sampled had higher soluble reactive phosphorus in porewater from the hyporheic zone than in surface water and ten sites had higher nitrate-plus-nitrite concentrations in the porewater. At seven of the 14 sites, the pressure difference between the surface water and porewater was measured to see if hyporheic water was coming into the river or if the river was losing water into the hyporheic zone. Three sites were upwelling and four sites were downwelling. At the upwelling sites, algae living on the river bottom would potentially have a rich nutrient source even when the surface water nutrient concentrations might be much lower, potentially limiting growth.